Comparative regeneration status in a natural forest and enrichment plantations of Chittagong (south) forest division, Bangladesh

M. Kamal Hossain[1], M. Lutfor Rahman[1], A. T. M. Rafiqul Hoque[1], M. Khairul Alam[2]

[1] *Institute of Forestry and Environmental Sciences, University of Chittagong, Chittagong-4331, Bangladesh*

[2] *Forest Botany Division, Bangladesh Forest Research Institute, Chittagong, Bangladesh*

Abstract: The natural regeneration of the tree species in pure natural forest stand and enrichment plantations of Baraitali Forest of Chittagong (South) Forest Division, Bangladesh was studied by stratified random quadrat method during April 2002 to November 2002. Totally 100 plots of 3 m X 3 m in size represents a total of 64 regenerating tree species from natural forest with an average seedlings of 24 767/hm^2, while only 40 regenerating tree species were recorded from enrichment plantations with an average seedlings of 18 633/hm^2. Maximum regeneration in natural forest was found with *Castanopsis* spp. (2200 seedlings/hm^2) followed by *Glochidion lanceolarium* (2183 /hm^2) whereas, in enrichment plantations maximum regeneration was found with *Dipterocarpus gracilis* (2117/hm^2) followed by *Anogeissus acuminata* (2000/hm^2). For natural forest, highest relative density was found for *Castanopsis* spp (8.88%), relative frequency for *Glochidion lanceolarium* (7.36%), relative abundance for *Syzygium* spp. (3.79%) and Importance Value Index were recorded with *Glochidion lanceolarium* (18.24%). The corresponding values for enrichment plantations were highest with *Dipterocarpus gracilis* (11.36%), *Glochidion lanceolarium* (9.71%), *Dipterocarpus gracilis* (5.92%), *Glochidion lanceolarium* (23.32%) respectively. Stem per hectare of some common trees with their seedlings and saplings in both the natural stands and enrichment plantations showed that only *Dipterocarpus gracilis* successfully recruited in both sites but recruitment was higher in natural forest. Like many other primary rain forests, the Baraitoli forest typically has both substantial seedlings and soil seed bank from which regeneration may occur. The naturally regenerated seedlings are quite dense but it could not reach the pole stage due to human interference.

Keywords: Regeneration; Natural forest; Enrichment plantations; Relative density; Frequency; Abundance; Importance Value Index

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Introduction

The tropical rain forests, covering only 7 percent of our planet's land surface (Villa-Lobos 1986; Lal 1998) but they contain more than half the species in the entire world biota (Wilson 1988; Lal 1998), are the most biologically diverse ecosystem. Bangladesh, lies in the northeastern part of south Asia on both sides of the Tropic of Cancer has rich biological heritage containing about 5700 species of angiosperms (Troup 1975; Khan 1977; Hossain 2001). However, biodiversity has been heavily disturbed during the past several decades (Hassan 1995). By the advent of the present century, the natural forests of Bangladesh have been cut over extensively, and most of the virgin forests were lost (Hossain et al. 1999). The rapid loss and degradation of forests in Bangladesh has brought about an alarming rate of depletion of native species (Rahman et al., 2000; Hossain, 2001). Natural regeneration is essential for preservation and maintenance of biodiversity (Anon 1992). Depending on management objectives, it is important to maintain the process of forest renewal by appropriate natural and artificial regeneration. The clear felling of natural forests not only accelerates loss of seedlings and saplings but also disturbs the natural condition of the forest and hence the ecosystem (Haque and Alam 1988). Natural regeneration is preferred due to the advantages with regard to low cost, site protection, genetic resources, diverse crop composition and flexibility of operations but fails due to lack of maintenance, intense logging, extraneous factors like browsing, uncontrolled fire (Champion and Seth 1968; Marn and Jonkers 1982); silviculture problem of seed production, seed dispersal (Baker 1950); inadequate research over natural forest and its conservation (Hossain et al. 1999). Knowledge about the pattern of natural regeneration is important to answer the basic question of forest management as when, where and how much to cut and how, when and what to regenerate (Hossain et al. 1999). Information on the composition and status of a forest is essential for its wise management in terms of economic value and regeneration potential (Wyatt-Smith 1987), but very scanty information is available of this forest. The lack of information hampers our ability to comprehend the magnitude of the loss of biodiversity and to formulate sustainable alternative for resource depletion. To conserve and manage our natural resources, we must know the status and

Biography: Corresponding Author: M. Kamal Hossain (1957-), male, Ph. D., Silviculture (UK) and Post Doc (Canada), Director and Professor in Institute of Forestry and Environmental Sciences, University of Chittagong, Chittagong-4331, Bangladesh. e-mail: hossainmk2001@yahoo.com

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structure of biological resources (CMGGR 1991; Smitinand 1995). Though measuring natural regeneration status is not easy and has remained a challenging task, the present study is an initiative to assess status of natural regeneration in both natural and enrichment plantations and compare between the two sites. It was felt that such a survey would be useful in forest management plan and also for arresting genetic erosion in the forest as improved understanding of succession factors and process may allow us to develop forest management system that benefit biodiversity conservation.

Study area and materials

The Baraitali Forest, which was classified as tropical rain forest rich in genetic resources, is one of the Forest Beats under Chunati Forest Range, which is not included in the Chunati Wildlife Sanctuary, in Chittagong (South) Forest Division, Bangladesh (Khan 1990; Mabud 2001). The forest is located at 21°48′ North latitude to 21°51′ North latitude and 92°04′ West longitude to 92°06′ West longitude (Anon, 1985), about 95 km south of Chittagong city. The Baraitali forest having a total area of 628.90 hm^2 of which Reserved Forest comprises 34.65 hm^2 and the rest are the protected forests. The soils on the alluvial plains and valleys are mainly silt loam to silty clay loam, moderately to strongly structured (WCMC 1998). The forest area is generally hilly to mountainous with gentle to steep slopes (Mabud 2001). The climate is typically sub-tropical, with a long dry season extending from November to April (Rahman and Hossain 2002). Rains are frequent and heavy in the monsoon season during the months of May to October and average rainfall is 2493 mm. (WCMC 1998; Rahman and Hossain 2002). Monthly temperature during spring can go down to as low as 19.1°C in the March and go up to as high as 32.7 °C in the month of April. Cold temperature occurs during winter and ranges from 14.2 °C (average minimum) to 29.5°C (average maximum) (WCMC 1998; Mabud 2001; Rahman and Hossain 2002).

Methods

The natural regeneration of the tree species in pure natural forest and enrichment plantations was studied by stratified random quadrat method during April 2002 to November 2002. Hundred (100) random plots (50 from natural forest area and 50 from enrichment plantation area) of 3 m × 3m in size were laid down and the optimum quadrat size was determined by applying the species area curve of Williams (1991). Plots are laid out in such a way as to cover proportional number of plots in different slopes and aspects. Within each quadrat, the name and number of seedlings with ≥ 20 cm in height and saplings of each species were counted. For each species the density, relative density, relative abundance, frequency, relative frequency, and Importance Value Index (IVI) were calculated following Mori *et al.* (1983), Boom (1986), Dallmeier *et al.* (1992) and Comiskey *et al.* (1994).

Results and discussion

The quantitative structure of the natural regeneration in natural forest and enrichment plantation area was studied based on the density, relative frequency, relative density, relative abundance and Importance Value Index.

Density

The study recorded 64 regenerating tree species from natural forest with an average number of seedlings of 24767/hm^2 and 40 regenerating tree species with an average seedlings of 18633 /hm^2 from enrichment plantation of Baraitali Forest (Tables 1 and 2). The regeneration of tree species in natural forest area was found maximum with Castanopsis spp. (2200 seedlings/hm^2) followed by *Glochidion lanceolarium* (2183 /hm^2), *Dipterocarpus gracilis* (1733 /hm^2), *Anogeissus acuminata* (1417/hm^2), *Cinnamomum* spp. (1250 /hm^2) and *Syzygium* spp. (1183 seedlings /hm^2). Whereas, regeneration per hectare in enrichment plantation area was maximum with *D. gracilis* (2117 seedlings /hm^2) followed by *A. acuminata* (2000 /hm^2), *G. lanceolarium* (1967/hm^2), *Holarrhena antidysenterica* (1383 /hm^2), *Castanopsis* spp. (1117/hm^2) and *Grewia microcos* (1000 seedlings /hm^2). The density of *D. gracilis, A. acuminata, G. lanceolarium, Castanopsis* spp. was found potential in both areas. The regeneration behavior of different tree species depends upon the presence of number of stems in different girth classes (Pande 2001). But, Rahman (2002) carried out the size class study of the same forest and found that only *D. gracilis* and *Castanopsis* spp. were well distributed in different d.b.h. classes but *A. acuminata* and *G. lanceolarium* were poorly distributed. The interactive influence of biotic and abiotic factors of the environment affects the survival and growth of seedling and sprouts (Howards 1973).

Relative density

Castanopsis spp. showed highest relative density (8.88%) in natural forest followed by *G. lanceolarium* (8.82%), *D. gracilis* (7.00%), *A. acuminata* (5.72%), *Cinnamomum* spp. (5.05%), *Syzygium* spp. (4.78%) and *Zizyphus oenoplia* (4.44%) (Table 1). But, in enrichment plantation area *D. gracilis* has highest relative density (11.36%) followed by *A. acuminata* (10.73%), *G. lanceolarium* (10.55%), *H. antidysenterica* (7.42%), *Castanopsis* spp. (5.99%) and *G. microcos* (5.37%) as shown in Table 2.

Relative frequency

The relative frequency in natural forest was highest with *G. lanceolarium* (7.36%) followed by *Castanopsis* spp. (6.13%), *Z. oenopia* (6.13%), *D. gracilis* (5.73%), *A. acuminata* (5.52%) and *G. multiloculare* (5.52%) (Table 1). Whereas, relative frequency in enrichment plantation was

highest for *G. lanceolarium* (9.71%) followed by *A. acuminata* (9.35%), *H. antidysenterica* (6.12%), *G. microcos* (6.12%), *D. gracilis* (5.40%), *Castanopsis* spp (5.40%) and *Syzygium fruticosum* (5.04%) (Table 2).

Table 1. Seedlings and saplings (hm^{-2}), relative frequency (RF), relative density (RD), relative abundance (RA) and importance value index (Ivi) of regenerating tree species in Baraitali natural forest, Chittagong (south) Forest Division

S.L.	Scientific Name	Seedlings /Hm^2	RF (%)	RD (%)	RA (%)	IVI (%)
001	*Glochidion lanceolarium*	2183	7.36	8.82	2.14	18.24
002	*Castanopsis spp.*	2200	6.13	8.88	2.59	17.52
003	*Dipterocarpus gracilis*	1733	5.73	7.00	2.18	14.83
004	*Anogeissus acuminata*	1417	5.52	5.72	1.85	13.03
005	*Zizyphus oenoplia*	1100	6.13	4.44	1.29	11.83
006	*Cinnamomum spp.*	1250	3.89	5.05	2.32	11.17
007	*Glochedion multiloculare*	1050	5.52	4.24	1.37	11.09
008	*Syzygium* spp.	1183	2.25	4.78	3.79	10.69
009	*Cassia nodosa*	933	3.68	3.77	1.83	9.22
010	*Grewia microcos*	933	3.27	3.77	2.06	9.03
011	*Garcinia cowa*	767	3.27	3.10	1.69	8.00
012	*Suregada multiflorum*	717	2.25	2.89	2.30	7.36
013	*Antidesma ghaesembilla*	683	2.86	2.76	1.72	7.28
014	*Dipterocarpus turbinatus*	533	1.43	2.15	2.69	6.18
015	*Syzygium fruticosum*	517	1.43	2.09	2.60	6.03
016	*Gardenia coronaria*	450	2.66	1.82	1.22	5.65
017	*Mangifera sylvatica*	433	1.43	1.75	2.18	5.29
018	*Duabanga grandiflora*	400	2.25	1.62	1.28	5.10
019	*Elaeocarpus robustus*	200	0.41	0.81	3.53	4.62
020	*Syzygium claviflorum*	300	0.82	1.21	2.64	4.58
021	*Pterospermum semisagitatum*	250	0.61	1.01	2.94	4.46
022	*Actinodaphne angustifolia*	283	2.04	1.14	1.00	4.15
023	*Randia uliginosa*	283	1.02	1.14	2.00	4.10
024	*Garuga pinnata*	100	0.20	0.40	3.53	4.01
025	*Ficus hispida*	267	1.64	1.08	1.18	3.85
026	*Croton* spp.	267	1.23	1.08	1.57	3.82
027	*Maesa ramentacea*	233	1.64	0.94	1.03	3.57
028	*Syzygium grande*	200	1.43	0.81	1.01	3.21
029	*Adina cordifolia*	167	0.61	0.67	1.96	3.18
030	*Vitex peduncularis*	167	1.43	0.67	0.84	2.92
031	*Oroxylum indicum*	150	0.61	0.61	1.76	2.92
032	*Chaetocarpus castanocarpa*	167	0.82	0.67	1.47	2.91
033	*Licuala peltata*	67	0.20	0.27	2.35	2.74
034	*Cassia fistula*	150	1.02	0.61	1.06	2.65
035	*Glycosmis arborea*	150	1.02	0.61	1.06	2.65
036	*Ficus* spp.	100	0.41	0.40	1.76	2.52
037	*Syzygium operculatum*	133	0.82	0.54	1.18	2.49
038	*Tetrameles nudiflora*	133	0.82	0.54	1.18	2.49
039	*Aphanamixis polystachya*	133	1.02	0.54	0.94	2.47
040	*Macaranga peltata*	83	0.41	0.34	1.47	2.16
041	*Pterocarpus indicus*	100	0.61	0.40	1.18	2.15
042	*Bursera serrata*	50	0.20	0.20	1.76	2.11
043	*Carallia brachiata*	100	1.02	0.40	0.71	2.11
044	*Symplocos racemosa*	50	0.20	0.20	1.76	2.11
045	*Trevesia palmate*	50	0.20	0.20	1.76	2.11
046	*Sapium baccatum*	67	0.41	0.27	1.18	1.81
047	*Artocarpus chma*	67	0.41	0.27	1.18	1.81
048	*Holarrhena antidysenterica*	67	0.82	0.27	0.59	1.65
049	*Ixora parviflora*	33	0.20	0.13	1.18	1.47
050	*Schima wallichii*	50	0.82	0.20	0.44	1.45
051	*Emblica officinalis*	50	0.61	0.20	0.59	1.38
052	*Pithecelobium angulatum*	33	0.61	0.13	0.39	1.13
053	*Alstonia scholaris*	17	0.20	0.07	0.59	0.84
054	*Litsea polyantha*	17	0.20	0.07	0.59	0.84
055	*Artocarpus lacucha*	17	0.20	0.07	0.59	0.84
056	*Vitex glabrata*	17	0.20	0.07	0.59	0.84
057	*Pavetta indica*	17	0.20	0.07	0.59	0.84
058	*Chaetocarpus castanocarpa*	17	0.20	0.07	0.59	0.84
059	Unknown (6 species)	1484	5.3	5.99	9.24	23.62
	Total	24767	100	100.00	100.00	300.00

Relative abundance

The abundance is usually expressed by assigning the species to one of the classes viz. rare, occasional, frequent, abundant and very abundant (Shukla and Chandal 1980). The species in order of relative abundance in natural forest were *Syzygium* spp. (3.79%), *G. pinnata* (3.53%), *Elaeocarpus robustus* (3.53%), *Pterosperrmum semisagitatum* (2.94%), *D. turbinatus* (2.69%), *S. claviflorum* (2.64%), *S. fruticosum* (2.60%) and *Castanopsis* spp. (2.59%) (Table 1). In enrichment plantation the relative abundance was highest for *D. gracilis* (5.92%), *S. claviflorum* (5.60%), *Maesa ramentacea* (4.62%), *Croton* spp. (4.37%) and *S. gracilis* (3.90%) (Table 2).

Table 2. Seedlings and saplings (hm^{-2}), relative frequency (RF), relative density (RD), relative abundance (RA) and importance value index (Ivl) of regenerating tree species in enrichment plantation Area of Baraital, Chittagong (south) Forest Division

S.L.	Scientific Name	Seedlings /hm^2	RF (%)	RD (%)	RA (%)	IVI (%)
001	*Glochidion lanceolarium*	1967	9.71	10.55	3.06	23.32
002	*Anogeissus acuminata*	2000	9.35	10.73	3.23	23.31
003	*Dipterocarpus gracilis*	2117	5.40	11.36	5.92	22.68
004	*Holarrhena antidysenterica*	1383	6.12	7.42	3.41	16.95
005	*Castanopsis* spp.	1117	5.40	5.99	3.12	14.51
006	*Grewia microcos*	1000	6.12	5.37	2.47	13.95
007	*Syzygium fruticosum*	867	5.04	4.65	2.60	12.29
008	*Syzygium* spp.	650	2.52	3.49	3.90	9.90
009	*Pterosperrmum semisagitatum*	617	2.88	3.31	3.23	9.42
010	*Maesa ramentacea*	550	1.80	2.95	4.62	9.37
011	*Glochidion multiloculare*	583	3.96	3.13	2.23	9.31
012	*Cassia nodosa*	517	3.60	2.77	2.17	8.54
013	*Croton* spp.	417	1.44	2.24	4.37	8.05
014	*Suregada multiflorum*	450	3.24	2.42	2.10	7.75
015	*Syzygium claviflorum*	267	0.72	1.43	5.60	7.75
016	*Antidesma ghaesembilla*	450	2.52	2.42	2.70	7.63
017	*Garcinia cowa*	383	2.88	2.06	2.01	6.95
018	*Emblica officinalis*	333	3.60	1.79	1.40	6.78
019	*Zizyphus oenoplea*	350	3.24	1.88	1.63	6.75
020	*Carallia brachiata*	367	2.16	1.97	2.56	6.69
021	*Calophyllum polyanthum*	250	1.08	1.34	3.50	5.92
022	*Azadirachta indica*	267	2.52	1.43	1.60	5.55
023	*Bursera serata*	150	0.72	0.81	3.15	4.67
024	*Pithecelobium angulatum*	183	1.08	0.98	2.56	4.63
025	*Duabanga grandiflora*	183	1.08	0.98	2.56	4.63
026	*Callicarpa arborea*	83	0.36	0.45	3.50	4.30
027	*Terminalia belerica*	167	1.44	0.89	1.75	4.08
028	*Vitex glabrata*	150	1.08	0.81	2.10	3.98
029	*Randia densiflora*	117	0.72	0.63	2.45	3.79
030	*Actinodaphne angustifolia*	100	1.44	0.54	1.05	3.02
031	*Aporosa dioica*	83	0.72	0.45	1.75	2.92
032	*Vitex peduncularis*	83	1.44	0.45	0.87	2.76
033	*Eravatamia divaricata*	50	0.72	0.27	1.05	2.04
034	*Ficus hispida*	50	0.72	0.27	1.05	2.04
035	*Sterculia foetida*	50	0.72	0.27	1.05	2.04
036	*Aphanamixis polystachya*	33	0.36	0.18	1.40	1.94
037	*Xanthophyllum flavescens*	33	0.36	0.18	1.40	1.94
038	*Bischofia javanica*	33	0.72	0.18	0.70	1.60
039	*Flacourtia jangorna*	17	0.36	0.09	0.70	1.15
040	Unknown (1species)	167	0.72	0.89	3.50	5.11
	Total	18633	100.00	100.00	100.00	300.0

Importance value index (IVI)

Sharma *et al.* (1986) estimated IVI by using relative basal area of the tropical savannah vegetation. Here, instead of basal area, number of seedlings was used to estimate IVI as per Shukla and Chandal (1980), Ahmed and Bhuyian (1994) and Hossain *et al.* (1999). However, the results give complete picture of phytosociological character of a species in the community. The species in order of Importance Value Index in natural forest were *G. lanceolarium* (18.24%), *Castanopsis* spp.(17.52%), *D. gracilis* (14.83%), *A. acuminata* (13.03%), *Z. oenoplia* (11.83%), *Cinnamomum* spp.

(11.17%), *G. multiloculare* (11.09%) and *Syzygium* spp. (10.69) (Table 1). Still, in enrichment plantation area, the species in order of Important Value Index was *G. lanceolarium* (23.32%), *A. acuminata* (23.31%), *D. gracilis* (22.68%), *H. antidysenterica* (16.95%), *Castanopsis* spp. (14.51%), *G. microcos* (13.95%) and *S. fruticosum* (12.29%) (Table 2).

The IVI values indicate the dominance of *G. lanceolarium*, *Castanopsis* spp, *D. gracilis*, *A. acuminata*, *Z. oenoplia*, *Cinnamomum* spp., *G. multiloculare* and *Syzygium* spp. in natural forest area. Whereas, *G. lanceolarium*, *A. acuminata*, *D. gracilis*, *H. antidysenterica*, *Castanopsis spp*, *G. microcos* and *S. fruticosum* were found to dominate in enrichment plantation area.

A comparison between the stems per hectare of some tree species with their seedlings and saplings shows that only *D. gracilis* successfully recruited in both sites of Baraitali forest but recruitment percentage of *D. gracilis* was found higher in natural forest (Table 3 and Table 4). Though *Castanopsis* spp., *G. lanceolarium, A. acuminata* was found profuse amount in regeneration plots but recruitment percentage of these seedlings was poor in both sites. The gap between the huge seedlings and successful recruitment of few trees is may be due to the individual silvicultural characteristics and requirements of each species and most importantly due to biotic interference.

Table 3. Stock of 6 major dominating seedlings and saplings with their stems per hectare showing recruitment percentage at Baraitali Natural Forest

Name of the species	Tree stems /hm^2	Seedlings /hm^2	%Recruited successfully
Dipterocarpus gracilis	103.0	1733	5.94
Syzygium spp.	43.5	1183	3.67
Castanopsis spp.	11.0	2200	0.5
Glochidion lanceolarium	7.5	2183	0.3
Cinnamomum spp.	2.0	1250	0.2
Anogeissus acuminata	0.5	1417	0.03

Table 4. Stock of 6 major dominating seedlings and saplings with their stems per hectare showing recruitment percentage at enrichment plantation area of Baraitali Forest

Name of the species	Tree stems /Hm^2	Seedlings /Hm^2	%Recruited successfully
Dipterocarpus gracilis	41.0	2117	1.93
Castanopsis spp.	9.0	1117	0.80
Anogeissus acuminata	2.5	2000	0.10
Glochidion lanceolarium	0.5	1967	0.02
Holarrhena antidysenterica	0.0	1383	0.00
Grewia microcos	0.0	1000	0.00

Considering the number of stems per hectare, relative density and relative frequency as a measure of success in re-afforestation, it is possible to re-establish a complete forest cover for the harvested area by the natural regeneration. Like many other primary rain forests, the Baraitali Forest typically has both substantial seedlings and soil seed bank from which regeneration may occur. Ahmed *et al.* (1992) estimated that the denuded hills of Chittagong, Bangladesh, could be brought under complete forest cover by natural regeneration at about 61% the cost of artificial plantings. Ahmed and Bhuyian(1994) carried out a similar study in Cox's Bazar Forest Division and observed that the average density was 45 982 seedlings per hectare and concluded that the study area could be brought under complete forest cover by natural regeneration. Haque and Alam (1988) also reported 79 700 seedlings per hectare in some blocks of Cox's Bazar Division. Hossain *et al.* (1999) also found 15 618 seedlings per hectare in a mixed tropical forest at Kaptai of Chittagong Hill Tracts (South) Forest Division. However, in comparison to the above studies, the regeneration in the Baraitali forest was low, though in comparison with the traditional plantations of 1.82 m×1.82 m spacing (3 018 seedlings/hm^2), the naturally regenerated seedlings are quite dense but due to human interference these could not reach the pole stage even.

Conclusion

The Baraitali forest is heterogeneous in nature and composition. Silivicultural characteristics of the different species of this area are not so far known. However, the important aspect is that a heterogeneous forest enhances prospects for the conservation of the total amount of biological diversity including protection of soil and water resources, maintenance of environmental stability and quality as well as maximum utilization of the forest resources (Mok 1992). Inadequate information on the species composition of the forest is one of the main problems confronting natural forest management, both in terms of the forests full economic value and its regeneration potential. In these cases, the present study of natural regeneration in Baraitali forest will provide the basic information of species composition, trends of successful recruitment of potential species and also to ensure that forest development is biologically, ecologically and environmentally sustainable. The present study shows a promising number of seedlings and saplings of the native species in natural forest stands. Careful maintenance and proper protection may enhance the seedlings to a successful natural forest with desirable native species.

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